Integrated Water Cycle Management in Kazakhstan

Tempus



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Editors:

Burghard C. Meyer

Leipzig University, Germany

Lian Lundy,

Middlesex University, London, UK

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- University of Cyprus, Nicosia, Cyprus
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- The Regional Environmental Centre for Central Asia, Almaty, Kazakhstan
- Kazakh Scientific Research Institute of Water Economy, Taraz, Kazakhstan
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- Fund Zhas Otan, Akmola region, Kokshetau, Kazakhstan

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Authors Index

List of contributing authors and contact details, together with identification of **sub-chapters (co-) authored**.

Abdullaev, Iskandar, the Regional Environmental Centre for Central Asia, CAREC, 40, Orbita-1, Almaty, 050043, Republic of Kazakhstan: IAbdullaev@carececo.org; 3.2, 7.1, 7.3.

Akbassova, Amankul; H.A.Yassawi International Kazakh-Turkish University, Ecology and Chemistry Department, Ecology Research Institute, 29, B. Sattarkhanov Avenue, Turkestan, 161200, Kazakhstan, ecolog_kz@mail.ru; 4.9.

Andreu, Joaquín, IIAMA (Research Institute Of Water And Environmental Engineering), Universitat Politècnica de València, Cno. de Vera s/n, 46022 Valencia, Spain; ximoand@upv.es; 2.3, 2.4, 2.5, 2.6.

Artsanov, Rustam, the Regional Environmental Centre for Central Asia, CAREC, 40, Orbita-1, Almaty, 050043, Republic of Kazakhstan: rarstanov@gmail.com; 7.1.

Asylbekova Saule, Kazakh Fisheries Research Institute, district -12, 1/1, Almaty, 050036, Kazakhstan. assylbekova@mail.rug; 5.9, 7.2.

Bayeshov, Abduali; D.V.Sokolsky Institute of Organic Catalysis and Electrochemistry, 142, Str. D. Kunaev, Almaty, 050010, Kazakhstan, bayeshov@mail.ru; 4.8.

Bazarbayeva, Tursynkul; Al-Farabi Kazakh National University, Energy and Ecology Department, 71. Al-Farabi Avenue, Almaty, 050040, Kazakhstan, nur_tyr2301@mail.ru; 6.3.

Bekbayev, Rahim; Kazakh scientific research institute of water economy, 12, Koigeldy Str, Taraz, 080003, Kazakhstan, bekbayev_55@mail.ru; 5.11.

Burkitbayev, Mukhambetkali; First Vice-Rector; Al-Farabi Kazakh National University, Al Farabi Avenue, Almaty, 050040, Kazakhstan, mukhambetkali.burkitbayev@kaznu.kz; Foreword.

Charré, Simon, Branch Office of the Regional Environmental Centre for Central Asia in the Kyrgyz Republic, 10 Erkindik Bul., Bishkek, 720040, Kyrgyz Republic, scharre@carececo.org; 7.1.

Dostay, Zhakypbay; Institute of Geography JSC National Scientific and Technological Holding Company "Parasat", Department of Water resources, Kabanbai batyr st./Pushkin st. 67/99, Almaty, 050010, Kazakhstan, zh.dostai@mail.ru; 5.4.

Dougall, Anne; Middlesex University, Department of Natural Sciences, The Burroughs, Hendon, London, NW4 4BT, UK, A.Dougall@mdx.ac.uk; 3.7.

Duskayev, Kassym; Al-Farabi Kazakh National University, Meteorology and Hydrology Department, 71. Al-Farabi Avenue, Almaty, 050040, Kazakhstan, kduskaev@gmail.com; 5.1, 5.3, 6.2, 6.3, 6.4.

Fatta-Kassinos, Despo, Nireas-International Water Research Center, School of Engineering, University of Cyprus, P.O. Box 20537, 1678 Nicosia, Cyprus: dfatta@ucy.ac.cy; 4.1, 4.2, 4.3, 4.4, 4.5.

Garelick, Hemda; Middlesex University, Department of Natural Sciences, The Burroughs, Hendon, London, NW4 4BT, UK, H.Garelick@mdx.ac.uk; 1,2, 2.7, 2.8, 3.7.

Hapeshi, Evroula, Nireas-International Water Research Center, School of Engineering, University of Cyprus, P.O. Box 20537, 1678 Nicosia, Cyprus, hapeshi.evroula@ucy.ac.cy; 4.1, 4.2, 4.3, 4.4, 4.5.

Haro, David, IIAMA (Research Institute Of Water And Environmental Engineering), Universitat Politècnica de València, Cno. de Vera s/n, 46022 Valencia, Spain. dahamon@upv.es; 2.4.

Hofner, Simone, United Nations Economic Commission for Europe, Palais des Nations, 1211 Geneva 10, Switzerland: simone.hofner@unece.org; 3.8.

Inozemtseva, Anna, the Regional Environmental Centre for Central Asia, CAREC, 40, Orbita-1, Almaty, 050043, Republic of Kazakhstan: AInozemtseva@carececo.org; 3.5.

Isbekov Kuanish, Kazakh Fisheries Research Institute, Mamur-3, 21/42, Almaty, 050036, Kazakhstan. isbekov@mail.ru; 5.9; 7.2.

Jones, Huw; Middlesex University, Department of Natural Sciences, The Burroughs, Hendon, London, NW4 4BT, UK, H.Jones@mdx.ac.uk; 2.7, 2.8, 3.4.

Kakabayev, Anuarbek; Sh. Ualikhanov Kokshetau State University, Geography and Ecology Department, 76, Abay Street, Kokshetau, 020000, Kazakhstan, anuarka@mail.ru; 5.10.

Kazangapova, Nurgul; Sh. Ualikhanov Kokshetau State University, Chemistry and Biotechnology Department, 76, Abay Street, Kokshetau, 020000, Kazakhstan, kazangapova@bk.ru; 5.5, 5.7.

Kurbaniyazov, Abilgazy; H.A.Yassawi International Kazakh-Turkish University, Ecology and Chemistry Department, 29, B. Sattarkhanov Avenue, Turkestan, 161200, Kazakhstan, abylgazy.kurbanyazov@iktu.kz; 5.6.

Lapuente; Enrique, IIAMA, I, Universitat Politècnica de València, Cno. De Vera s/n, 46022 Valencia, Spain, enlaoj@hma.upv.es; 1.3, 1.4.
Lerma, Néstor, IIAMA (Research Institute Of Water And Environmental Engineering), Universitat Politècnica de València, Cno. de Vera s/n, 46022 Valencia, Spain, nestorlerma@upv.es; 2.3.
Lundy, Lian; Middlesex University, Department of Natural Sciences, The Burroughs, Hendon, London, NW4 4BT, UK, L.Lundy@mdx.ac.uk; Editor, Introduction, 1.1, 1.5, 3.6, 6.1, 7.4; Glossary.
Martin, Miguel, IIAMA, I, Universitat Politècnica de València, Cno. De Vera s/n, 46022 Valencia, Spain, mmartin@hma.upv.es; 1.3, 1.4.
Meyer, Burghard, Leipzig University, Institute of Geography**.** Johannisallee 19a, 04103 Leipzig, Germany. Burghard.meyer@olanis.de; Editor, Introduction, 1.6, 2.2, 3.3, 5.2, 5.3, 6.1, 7.4; Glossary, Index.
Michael, Irene, Nireas-International Water Research Center, School of Engineering, University of Cyprus, P.O. Box 20537, 1678 Nicosia, Cyprus, michael.irene@ucy.ac.cy; 4.1, 4.2, 4.3, 4.4, 4.5.
Minzhanova, Guldana; Al-Farabi Kazakh National University, Energy and Ecology Department, 71. Al-Farabi Avenue, Almaty, 050040, Kazakhstan, guldana.m@mail.ru; 5.1, 6.2, 6.3, 6.4.
Molina. Jose luis Alonso, Research Institute of Water and Environmental Engineering, Universitat Politecnica de Valencia, Cno. de Vera s/n, 46022 Valencia, Spain. jalonso@ihdr.upv.es; 1.2.
Momblanch, Andrea, IIAMA (Research Institute Of Water And Environmental Engineering), Universitat Politècnica de València, Cno. de Vera s/n, 46022 Valencia, Spain; anmombe@upv.es; 2.5.
Nurdillayeva, Raushan; H.A.Yassawi International Kazakh-Turkish University, Ecology and Chemistry Department, 29 B. Sattarkhanov Avenue, Turkestan, 161200, Kazakhstan, raushan.nurdillayeva@iktu.kz; 4.7, 4.8.
Nurmukhanbetova, Nurgul; Sh. Ualikhanov Kokshetau State University, Chemistry and Biotechnology Department, 76, Abay Street, Kokshetau, 020000, Kazakhstan, nn_nurgul@mail.ru; 5.5.
Paredes-Arquiola, Javier, IIAMA (Research Institute Of Water And Environmental Engineering), Universitat Politècnica de València, Cno. de Vera s/n, 46022 Valencia, Spain; jparedea@hma.upv.es; 2.3, 2.4, 2.5, 2.6.
Pedro-Monzonis, María, IIAMA (Research Institute Of Water And Environmental Engineering), Universitat Politècnica de València, Cno. de Vera s/n, 46022 Valencia, Spain. mapedmon@hotmail.com; 2.3; 2.6.
Purchase, Diane; Middlesex University, Department of Natural Sciences, The Burroughs, Hendon, London, NW4 4BT, UK, D.Purchase@mdx.ac.uk; 1.2.
Pyatov, Evgeniy; JSC "Kokshetau mineral water", Vice President of Science, North Industrial Area, PO Box 926, Kokshetau, 02000, Kazakhstan, pyatov@yandex.ru; 4.6.
Rakhmatullaev, Shavkat, National water Management expert of the Transboundary water management in Central Asia/German International Cooperation (GIZ), Republic of Uzbekistan: shavkat.rakhmatullaev@giz.de; 3.2.
Romanova, Sofia; Al-Farabi Kazakh National University, General and Inorganic Chemistry Department, 71, Al-Farabi avenue, Almaty, 050000, Kazakhstan, vivarom@mail.ru; 5.5, 5.7.
Salnikov, Vitaliy; Al-Farabi Kazakh National University, Meteorology and Hydrology Department, 71, Al-Farabi Avenue, Almaty, 050040, Kazakhstan, vitali.salnikov@kaznu.kz; 5.3.
Schmidt Ronny, Leipzig University, Institute of Geography. Johannisallee 19a, 04103 Leipzig, Germany. ronny.schmidt@uni-leipzig.de; 1.7.
Schneider, Christian, Leipzig University, Institute of Geography. Johannisallee 19a, 04103 Leipzig, Germany. christian.schneider@uni-leipzig.de; 1.7, Index.
Schreiner, Vera, Leipzig University, Institute of Geography**.** Johannisallee 19a, 04103 Leipzig, Germany. Vera_schreiner@yahoo.de; 5.2.
Shakirova, Tatiana, the Regional Environmental Centre for Central Asia, CAREC, 40, Orbita-1, Almaty, 050043, Republic of Kazakhstan: tshakirova@carececo.org; 3.8.
Shalgimbayeva Gulmira, Kazakh Fisheries Research Institute, Zarokova 269/52 Almaty, 050056, Kazahkstan. Shalgimbayeva@mail.ru; 5.9, 7.2.
Solera, Abel, IIAMA (Research Institute Of Water And Environmental Engineering), Universitat Politècnica de València, Cno. de Vera s/n, 46022 Valencia, Spain; asolera1@gmail.com; 2.3, 2.4, 2.5, 2.6.
Strikeleva, Yekaterina. the Regional Environmental Centre for Central Asia, CAREC, 40, Orbita-1, Almaty, 050043, Republic of Kazakhstan: estrikeleva@carececo.org; 3.5.
Toregozhina, Zhanna; Al-Farabi Kazakh National University, Energy and Ecology Department, 71. Al-Farabi Avenue, Almaty, 050040, Kazakhstan, zhan_tore@mail.ru; 6.4.

Toumazi, Toumazis, Nireas-International Water Research Center, School of Engineering, University of Cyprus, P.O. Box 20537, 1678 Nicosia, Cyprus, toumazi.toumazis@ucy.ac.cy; 4.1, 4.2, 4.3, 4.4, 4.5.

Vasquez, Marlen Ines, Nireas-International Water Research Center, School of Engineering, University of Cyprus, P.O. Box 20537, 1678 Nicosia, Cyprus, vasquez.marlen@ucy.ac.cy; 4.1, 4.2, 4.3, 4.4, 4.5.

Watt, John; Middlesex University, Department of Natural Sciences, The Burroughs, Hendon, London, NW4 4BT, UK, J.Watt@mdx.ac.uk; 2.1, 3.1, Introduction.

Wildeboer, Dirk; Middlesex University, Department of Natural Sciences, The Burroughs, Hendon, London, NW4 4BT, UK, D.Wildeboer@mdx.ac.uk; 2.7, 2.8.

Zavialov, Peter; P.P.Shirshov Institute of Oceanology, Laboratory of land-ocean interactions and the anthropogenic impact, 36, Nakhimovski Avenue, Moscow, 117997, Russia, peter@ocean.ru; 5.6.

Zhanabayeva, Zhanara; Al-Farabi Kazakh National University, Meteorology and Hydrology Department, 71. Al-Farabi Avenue, Almaty, 050040, Kazakhstan, zhanusik9@mail.ru; 6.2.

Zhaparkulova, Ermekul; Kazakh scientific research institute of water economy, 12, Koigeldy Str, Taraz, 080003, Kazakhstan, ermekull@mail.ru; 5.11.

Zharkinbekov, Temirkhan; Sh. Ualikhanov Kokshetau State University, first vice-rector, 76, Abay Street, Kokshetau, 020000, Kazakhstan, zharkinbekov_t@mail.ru; 5.8.

Zhylysbayeva, Akkongyr; H.A.Yassawi International Kazakh-Turkish University, Ecology and Chemistry Department, 29, B. Sattarkhanov Avenue, Turkestan, 161200, Kazakhstan, akkonyr@mail.ru; 4.7, 4.8.

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Chapter 7

Transboundary Catchment Issues and Future Integrated Management

7. Transboundary catchment issues and future integrated management

7.1 Transboundary mountain ecosystems

Rustam Artsanov, Iskandar Abdullaev, Simon Charré

E-mail address: IAbdullaev@carececo.org

Introduction

Ecosystems provide humans with a wide range of vital services including regulatory services (carbon sequestration and climate regulation, waste decomposition, purification of water and air, crop pollination, disease control), supply services (crops & food, water, energy including hydropower and biomass fuels) and supporting services (nutrient dispersal and cycling, seed dispersal, primary production) (MEA, 2005). The section will describe the major trans-boundary ecosystems in Central Asia, their functions value for the economic stability and environmental sustainability in the region, and the current degradation they are experiencing.

Crucial water related ecosystems in Central Asia such as mountains, rivers and lakes follow natural boundaries rather than political borders. Policies and practices in one country may affect the regulating, supply and supporting functions of water related ecosystems with implications that concern the whole region. Such implications include the deterioration of water quality and public health, decrease in land productivity, increased natural risks, poverty, migration and a high risk of regional conflicts.

Particularly, in Central Asia, mountain ecosystems are a unique source of fresh water. A cascade of water reservoirs used for irrigation and power generation controls the runoff of most of the main rivers. Many small rivers originate at the foothills as a result of underground runoff discharge, from which water is used to irrigate agricultural lands in the piedmont valleys. The runoffs of such large rivers as the Ili, Shu, Talas, Syrdarya, Amudarya, Zeravshan, Atrek, Karatal, Aksu and Lepsaare form in high altitude, mainly in Kyrgyzstan and Tajikistan. Other countries are considered as exporters of fresh water.

Another interesting example of significant transboundary mountain ecosystem in Central Asia is forest ecosystems. Central Asian forest resources stretch over a limited area due to harsh climatic conditions and past periods of intensive logging. Remaining forests are mainly concentrated in mountain areas. They are of limited significance in economic terms and account for very little in Central Asian States' gross domestic product (GDP). For instance, forests' contribution to the domestic economy of the Kyrgyz Republic, as the gross output of forestry and game sector, is 97.6 million KGS (approx. US$ 2 million) or about 0.1% of GDP (FAO, 2010). In the meantime, mountain forests of Central Asia are of great biological and genetic interest. For instance, the Tien-Shan Mountains are home for a unique spruce forest belt formed by the relic species of Tien-Shan spruce, as depicted by the picture b, figure 7.1.1. The western part of the range is famous for its Zeravshan juniper woodlands. The wild fruit tree belt stretching across the piedmonts constitutes a unique genetic resource for cultivated varieties of apple, pear, pomegranate, apricot, and other. In addition to this, mountain forests are a crucial source of timber and fuel wood, fruits, berries, medicinal plants which sustains livelihood of rural communities without often being incorporated in the economy. Mountain forests, through the regulating ecosystem services they provide, play also an important role in preventing soil erosion and protecting downstream communities from floods, landslides and other natural disasters. Finally, they are a rare type of ecosystem in the region and provide habitats to a large number of wild animals, including endangered fauna and flora species.

Central Asian Mountain ecosystem classification

Several attempts have been made to classify ecosystems using globally recognized approaches (USGS, 1997) and applying them to sub-regional scale. The table 7.1.1 presents the classification developed by the Regional Environmental Center for Central Asia, specifically for mountain ecosystems (CAREC, 2004).

Table 7.1.1 Classification of the Central Asian mountain ecosystems

Ecosystem class	Sub-types
1. Desert ecosystems	1.1. Piedmont desert ecosystems (Northern Tien Shan) 1.2. High mountain desert ecosystems (Eastern Pamir)
2. Semi-desert ecosystems	2.1. Piedmont short grass -ephemerous-ephemeroid- semi savanna ecosystems (Western Tien Shan) (picture c, figure 7.1.1) 2.2. Piedmont and low mountain tall forb and tallgrass ephemerous-ephemeroid ecosystems (Western Tien Shan, Kopet-Dag) 2.3. Mid-altitude mountain ephemeroid-sagebrush (Western Pamir, Badakhshan)
3. Steppe ecosystems	3.1. Low mountain steppe ecosystems (Northern Tien Shan) 3.2. Mid-altitude mountain steppe ecosystems (Northern and Central Tien Shan) 3.3. Mountainous-xerophyte-steppe ecosystems of mid altitude mountain belt (Western Pamir, Badakhshan, Kopet-Dag) 3.4. High mountain steppe ecosystems (Central Tien Shan, Syrty of Internal Tien Shan, Eastern Pamir).
4. Forest ecosystems	4.1. Piedmont and low mountain xerophyte open woodland ecosystems (Western Tien Shan, Kopet-Dag, Western Pamir) 4.2. Wild fruit-bearing (apple, apricot) tree groves and bushes (Northern and Western Tien Shan) 4.3. Open woodland haw and pistachio ecosystems (Western Tien Shan) 4.4. Small- leaved (birch and aspen) ecosystems (Northern Tien Shan) 4.5. Maple trees (Western Tien Shan) 4.6. Walnut ecosystems (Western Tien Shan) 4.7. Spruce forest ecosystems (Northern Tien Shan) (picture b, figure 7.1.1) 4.8. Juniper forests and open woodlands (Western Tien Shan, Kopet-Dag, Western Pamir) 4.9. Mountain tugai ecosystems (in river valleys)
5. Meadow ecosystems	5.1. Mid- and tall grass meadows of mid-altitude mountain belt (Northern and Western Tien Shan) 5.2. Sub-alpine meadows and juniper elfin wood (Northern and Western Tien Shan) 5.3. Alpine short grass and Cobresia meadows (Northern, Western and Central Tien Shan) and Cobresia meadows (Northern Tien Shan)
6. High mountain cushion plant formation	6.1. Continental cold-temperate ecosystems (Western Pamir, Badakhshan, Central Tien Shan) 6.2. Ultra-continental warm-temperate ecosystems (Eastern Pamir)
7. Nival ecosystems	7.1. Moraines 7.2. Eternal snow 7.3. Glaciers (picture d, figure 7.1.1)
8. Water ecosystems	8.1. Rivers (picture a, figure 7.1.1) 8.2. Mid-altitude mountain lakes 8.3. High mountain lakes 8.4. Artificial reservoirs
9. Agro-ecosystems	9.1. Agricultural sites 9.2. Dacha sites
10. Urban-ecosystems	10.1. Mountain villages of up to 500 inhabitants 10.2. Mountain villages of more than 500 inhabitants 10.3. Towns, Cities 10.4. Recreation sites (sanatoriums, rest houses etc.)

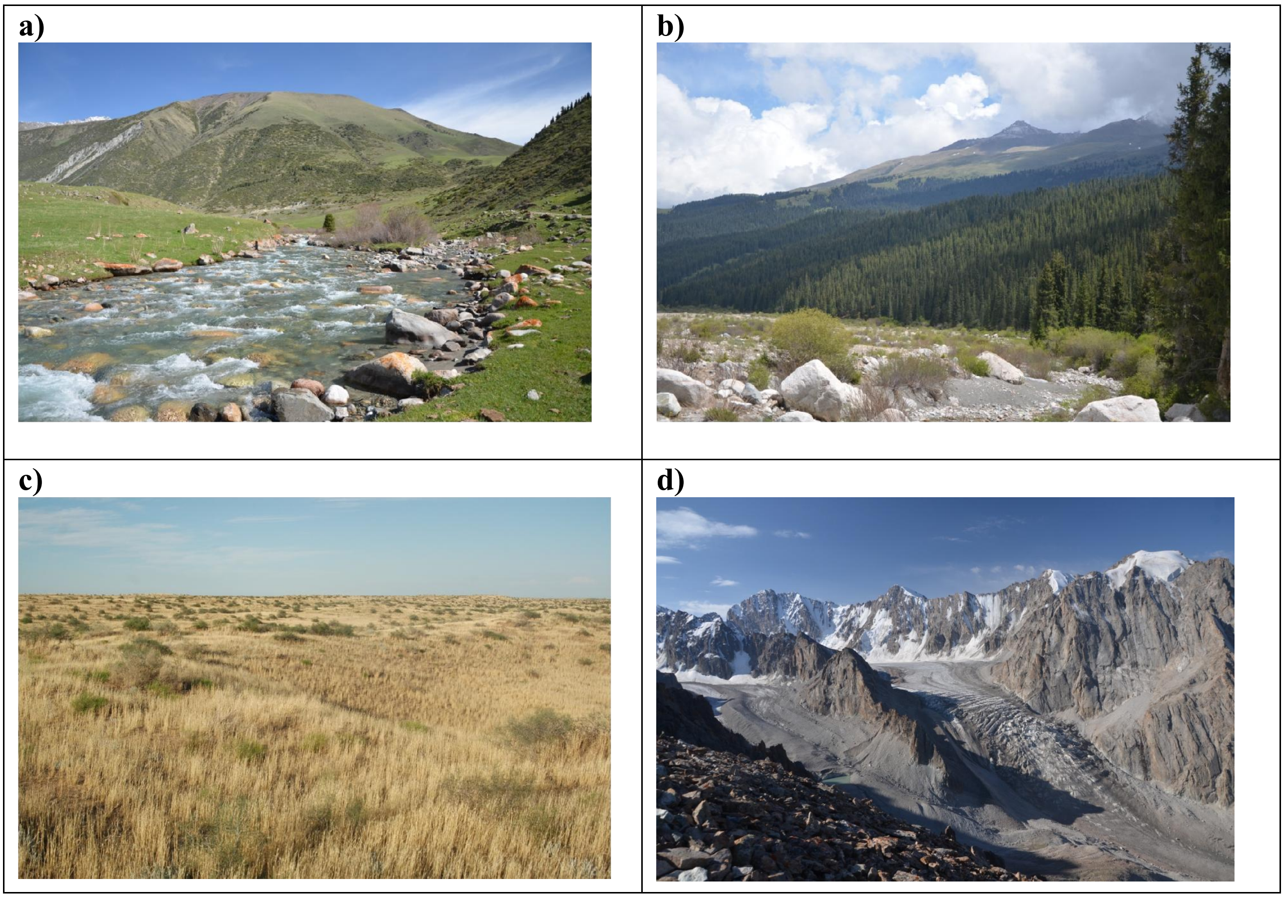

Figure 7.1.1 Various types of ecosystems: a) mountain river; b) mountain spruce forest; c) semisavanna; d) high mountain

Central Asian ecosystem deterioration

The impacts of human activities combined with the effects of climate change and direct human activity contribute to the destruction of the natural ecosystems in Central Asia. The biodiversity and the biomass is reduced through logging, harvesting of medicinal herbs and aesthetically attractive plants, hunting, fishing, grazing and hay-making, but also and indirectly reduces the volume of natural biomass through environmental pollution, destruction of wildlife habitats, construction of roads, settlements, mining enterprises, reservoirs and other facilities. As a result of the fragmentation and reduction of habitats, most species have become endangered. Several animal and plant species of animals and plants in Central Asia have disappeared, such as the wild pomegranate, the Turanian tiger, the red wolf, and others (UNDP, 2006). Following the transformation of aquatic and water-related ecosystems and their direct exploitation, more than 50 species of fish, about 40 species of birds, 20 species of mammals, 4 amphibians many of which were included in the IUCN List are referred to as threatened species.

The reduction of water resources and the deterioration of water quality may affect agricultural productivity and damage food security in the region. For example, overuse of irrigation water together with inadequate drainage systems has caused large-scale land degradation in downstream areas of the region, which is mainly fed by two main rivers, the Amu-Darya and Syr-Darya. Recent studies show that more than 50% of irrigated soils are salt-affected in Central Asia (Qadir et al., 2009). The use of saline water without appropriate management can result in the accumulation of salts in the root zone with associated negative impacts on crop productivity. The population of the dry land areas in the downstream countries may experience hunger, the spread of pandemic diseases and may be forced to migrate.

Causes of ecosystems degradation

The following environmental policy and management causes of ecosystems degradation in Central Asia are mentioned in the available literature:

- Ecosystem management is often regulated by market mechanisms focusing on short-term benefits and neglecting future outcomes;
- There is no clear definition of property rights for some ecosystems and the natural resources they provide;
- There is a lack of integrated regional development projects and programs;
- Compliance with national environmental laws and Multilateral and Bilateral Environmental Agreements (MEA's) is not properly enforced;
- Financial and institutional capacity of the relevant state agencies is limited and the state control over protected territories is weak: the staff salaries are low so that they are even involved into illegal logging;
- Low level of environmental education results in consumerism as a prevailing attitude towards wild nature. In the inherited Soviet system of education there were no subjects solely dedicated to environmental science. The tariffs for the main utilities were traditionally low due to government subsidies. Thus, the value of natural resources is not acknowledged;
- Civil society and the NGO's are limited in their capabilities of integrating community interests into the development agenda;
- Natural bioresources are the main source of living for people in remote areas. For example, in the Kyrgyz Republic 60 percent of the population are farmers strongly relying on pastures;
- There is a lack of efficient mechanisms for settling transboundary disputes between various users of natural resources;
- Tariff policies are based on state subsidies for water and electricity resulting in low incentives for water/energy savings;
- Countries are lacking methodologies for national and transboundary environmental economic assessments of ecosystems;
- National monitoring systems to monitor the state of ecosystems and natural resources are weak (GWP, CAREC, 2006)(CAREC, 2004).

Activities for improvement

In order to improve the state of ecosystems, Central Asian countries should implement a range of activities at national and regional levels including the following:

- Developing regional action plans for transboundary ecosystems management;
- Introducing resource-saving technologies and achieving the minimum level of resources loss;
- Measure the minimum water flow and maximum discharge for ecological sustainability of rivers, and identify measures for improving the condition of aquatic ecosystems;
- Implementing controls over transboundary pollution and related disasters;
- Implementing assessment, reproduction, and growth of biological resources;
- Rehabilitating vegetation cover in the zones of runoff formation and consumption;
- Enhancing environmental monitoring system and the control for discharges of pollutants into the environment;
- Developing methods for ecosystem services valuation;
- Developing public awareness and public participation.

Conclusion

Taking into account the requirements of the international conventions, legal frameworks of Central Asian States should be harmonized at the level of regional agreements and memoranda. All basin agreements related to water and other resources shall be based on enforcement of preservation and protection of ecosystems and integrated water resources management. The agreements should outline the order of consultations and effective mechanisms for notification, control, and mitigation of transboundary impacts, including detection and measurement of pollution, definition of its origin, and general monitoring of the environment at the transboundary level.

7.2 Current situation and development of bio-resources of the Transboundary Rivers Ili and Irtysh in Kazakhstan

Saule Asylbekova, Kuanish Isbekov, Gulmira Shalgimbayeva

E-mail address: assylbekova@mail.rug

Introduction

Water management strategies implemented by neighboring states (e.g. People's Republic of China) within transboundary Ili and Irtysh rivers have an enormous impact on the value and quality of biological resources (such as fishery stock) of Kazakhstan. The deterioration of water regimes (e.g. reduced flows) and associated reductions in the bio-efficiency of fishery reservoirs may be due to the implementation of water programs by neighboring states'. For example, there is a risk that the planned increase of water intake by China from the upper reaches of rivers Ili (up to 4.0 km^3 per year) and from Irtysh (up to 5 km^3 per year), will significantly reduce the volume of cross-border flows and worsen the already shrinking levels of reproduction of valuable fish species (carp, pick-perch) in the Ili -Balkhash and Zaysan-Irtysh water basins (KazRIF, 2010). The map of the Zaysan-Irtysh river basin is presented in Figure 7.2.1. The Irtysh River originates in the territory of the People's Republic of China and is known there as Black Irtysh.

The Black Irtysh flows into Lake Zaysan and the Bukhtarma reservoir. These reservoirs (Zaysan and Bukhtarma) are the largest fishing reservoirs in eastern Kazakhstan, with annual catches of 8-10 thousand tons of different species of fish anticipated. However, in recent years the water level in these reservoirs has decreased and low-water years become more frequent, which negatively affects the volume of fish catch. According to the studies by Kulikov (2003), in a low water year when reservoirs receive input flow volumes <3 km3, storage reservoir of Bukhtarma is divided into two parts by this process thus entailing catastrophic consequences for biocoenosis. Decreased water levels are associated with the upstream diversions of water runoffs to the Black Irtysh River resulting in the loss of the richest spawning areas in the Irtysh River delta.

The total area of the Black Irtysh delta is 625 km^2 (KazRIF, 2011), of which approximately 415 km^2 are spawning areas for fish. If, for example, China increases its consumption of water from this water body to 2,1 km^2 annually, the loss of spawning areas within the Irtysh delta would decrease by 120-150 km^2 (30-35% respectively) .A further issue is the quality of water entering Kazakhstan from neighboring countries, with elevated levels of e.g. metals recorded in Black Irtysh periodically creating difficult conditions for aquatic organisms (Kulikova & Kulikov,withour year). This issue is being addressed; for example, agreements with China on monitoring pollution of the Black Irtysh River (including implementation of a programme on transboundary environmental monitoring within both Kazakhstan and China) have been signed, which have led to pollution reduction. Unlike the Irtysh River, 76% of flow the river Ili are is formed within the territory of China. Hence, the existence of the Ili-Balkhash water basin is completely dependent on the water policy in China.The Ili River is the main water artery of Lake Balkhash. The Ili Balkhash basin covers both the territory of Kazakhstan and China. In the upper reaches of the Ili River on the

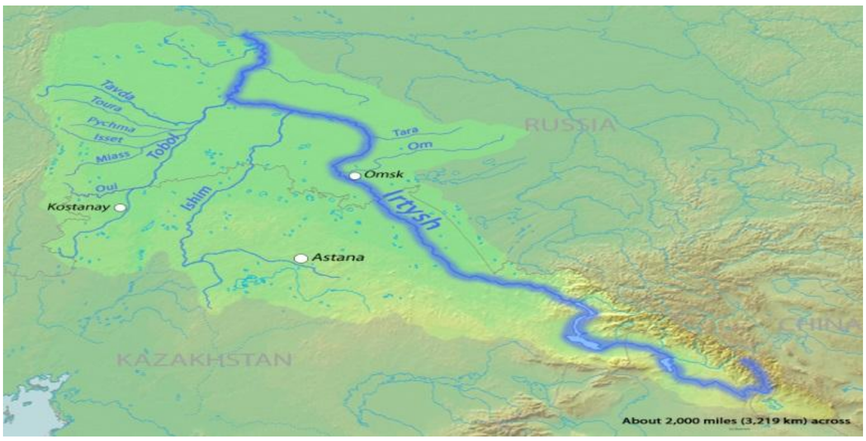

Figure 7.2.1 Map of the Zaysan-Irtysh river basin (Wikipedia, undated)

territory of Xinjiang (China), large hydro-technical facilities for irrigation and power generation are being constructed.

western part of Lake Balkhash would fall to 338 mBS, and in the eastern part of the lake it will drop to 332.2 mBS (Kenzhebekov 2013).

Figure 7.2.2 Map of the Ili-Balkhash water basin region (Wikipedia, undated)

The Chinese water management system of the Ili river consists of 14 reservoirs and 58 power plants. In 2000, KazRIF began monitoring the quality of transboundary flows to Kazakhstan from China and its impact on the ecology and fisheries of the Ili-Balkhash basin.Among the pollutants idntified as being of significant risk to water resources are heavy metal ions, the concentration of which in recent high-water level years decreased to safe levels.

It is predicted that by reducing the flow volumes in the River Ili on Kazakhstan territories by 40 %, the water level in Lake Balkhash would be 341.93 mBS (meters above the sea level as defined using the Baltic altimetry system); in an average-water year the level would be 340mBS and in low-water years Balkhash Lake would divide into two parts (western and eastern areas). The water level in the

Conclusion

The studies presented here clearly illustrate the scale of challenges and associated impact of sharing waters across national boundaries, strongly underlining the need for water resources to be managed on a catchment (as opposed to national boundary) basis. Increased water extraction from the Ili River in low-water years will transform Lake Balkhash from one large water body to a series of scattered small water volumes. The eastern part of Lake Balkhash would lose fishery importance due to the high salinity while in the Western Balkhash increases in water mineralization will also lead to a reduction in fish stocks, with these negative environmental impacts leading to serious social and economic consequences both local regional ones. It should be noted that currently there is no revised up-to-date data on the volumes of water extracted from the rivers Irtysh and Ili in e.g. China. However, based on available scientific publications, the volume of water intake in the upper reaches of the Ili and Irtysh are tentatively estimated to be in the region of 4 and 5 km^3 per

Table 7.2.1 Concentration of heavy metals in the Ili river, 2013 (upstream) (in mg/l). Key: SWC = surface water concentration; MPC = maximum permissable concentration (Izmailov, 1990)

Cd		Cu		Pb		Zn		Ni	
SWC	MPC	SWC	MPC	SWC	MPC	SWC	MPC	SWC	MPC
0,0	5,0	2,0	10,0	0,8	10,0	2,4	10,0	1,9	10,0

year, respectively. These volumes are taken into account when preparing the preliminary predictive calculations on the impact of the runoff reduction on environmental status of transboundary waters bordering on China.

7.3 Challenges of Transboundary cooperation

Iskandar Abdullaev

E-mail address: IAbdullaev@carececo.org

Present Challenges

Central Asian nations are going through political, economical and social changes since independence. The transition causes long-term impact on water sector, which was once the second largest user of the state funds during the Soviet times (Abdullaev and Atabaeva.2012). Growing economic crisis and limited funding capacities of national states after the independence have reduced inflow of finances into the water sector which reduced the influence and the role of water bureaucrats in nation building. The reforms in agriculture and other sectors of economy have seriously changed situation in water sector. In two out of five countries - the Ministry of Water Resources remains an individual agency; in one country it was merged with agriculture department but still has separate remit; in the remaining two countries, the water management department forms part of the Environmental Agency. Although these changes in water sector took place at the national level, they have far reaching impact on regional level. In the last few years, the issues of water management in Central Asia became political issues: the role of a technocrat–water manager has been reduced from active agenda setter to that of an observer (Dukhovniy et al. 2008). This paper highlights the importance of an integrated approach to water sector reforms that will enhance the efficiency of water resources management and increase the likelihood of cooperation between the regional countries on water management.

Central Asia is the home to 60 million people and it is one of the world's political, social and economical "hot spots". Water is a crucial element for future sustainability of the region; it is an important factor for food and energy production as well as environmental sustainability. The multitudes of water management issues in the Central Asian states are interlinked. Socio-political and economical transformations in the last two decades have contributed greatly to the changes in water sector (Abdullaev and Rakhmatullaev, 2003). Limited capacities of water institutions, inefficient water management and lack of coordination result in competition and contestation for water at all levels. New agricultural policies, economic growth in other sectors in each country help to shape these new water policies, but these policies are the outcome of overall national policies of individual state. With such disparity in the policy framework between different states it requires a more integrated, transboundary co-operation to improve water management in the region.

Changes in Different Levels (Transformations)

Since independence, the Central Asian states went through political, economical and social transformations to develop their nationhood. Institutions set up during the Soviet era were either abolished or transformed into different organizations in different states. The water reforms in the Central Asia states have been slow due to the sudden collapse of institutional and financial infrastructure of water sector. This was further exacerbated by the destruction of scientific research and practical networks and the failure of the "blue print" approaches of the recent water reforms (Dukhovniy et al. 2008). In addition, the huge and inefficient infrastructure operation required water professionals to focus on delivering practical solutions rather than on institution building. Environmental reforms in other sectors, especially in agriculture, also complicated the problem by increasing contestation and competition for water resources at the local level. Water management in the basin level became chaotic and irregular; the national water systems lacked of consistency and continuity; and the regional (transboundary) level cooperation lost its initial genuinely designed purposes, became political playground for differing interests between the riparian states (Figure 7.3.1).

Changes in the water sector are evident at the local level where the number of water users has increased manifold due to agricultural reforms. Collective farming has been abolished; individual, private farming became the major form of agricultural produce. Competition and contestation became a regular issue of the everyday water management. New national states instated new policies with socio-economic control by state institutions to replace the state-centric, closed and authoritarian system. Differing water governance regimes thus play an important role in formation of the national water policies. Regional hydro policies once being an internal issue of the Soviet regime now became the battleground of interests of the riparian states. Upstream-downstream, energy vs. irrigation interests regularly clash at this level and result in tensions between the Central Asian states over water resources.

Although these three policies (everyday, national and regional) could be seen as separate aspects of water resources management, in reality, they were inter-dependent and fed into each other.

Nation Building Efforts (Internal and External)

Since independence in the1990s, countries of Central Asia have been building up national institutions such as legal system, government structures, military and police forces. Sudden collapse of the Soviet system created emerging challenges that required urgent attentions. The immediate internal and external threats demanded most of the resources of the new states as nation building became the most important task for all tiers of the government. Initially, nation building was concerned mostly with internal aspects of the process, setting up state apparatus and legislation. Since the early 2000s, the regional states have started to put in order more external aspects of nation building: border, shared infrastructure and resources (water).

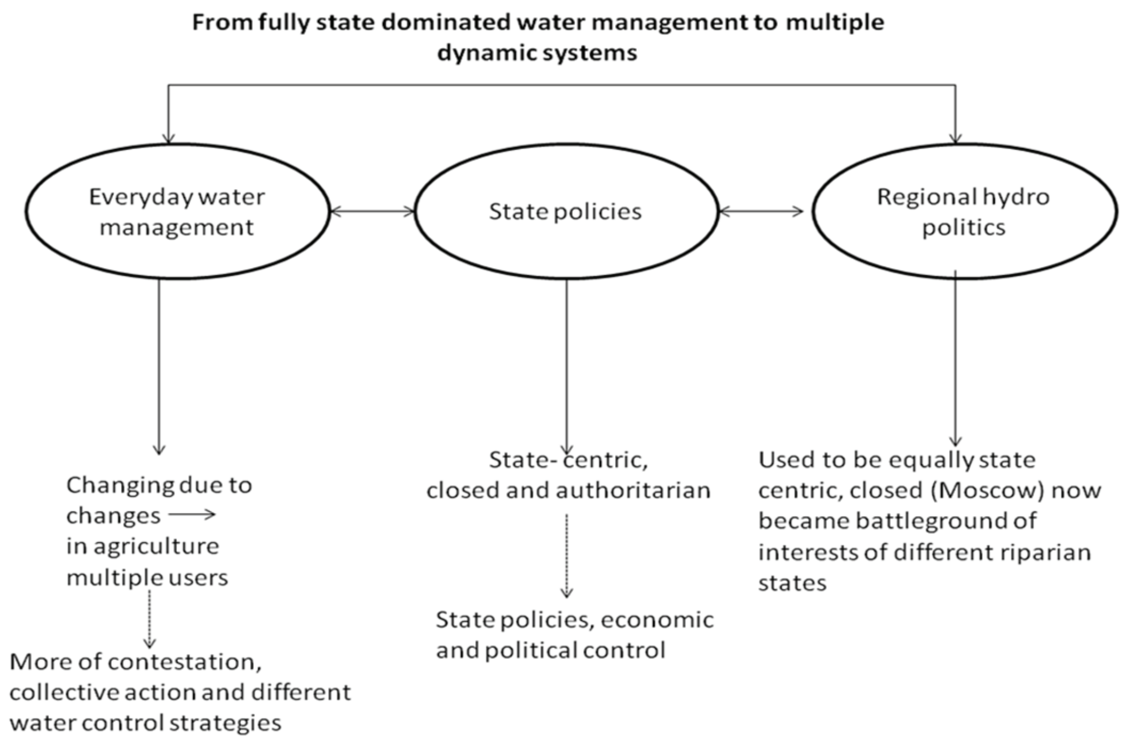

Figure 7.3.1 Changes in three levels of water management (Abdullaev and Atabaeva, 2012)

Coherent solutions on everyday water management issue could reduce competition for water resources from different locations and reduce pressure on national water management system. This could provide time and resources for elaboration to produce effective national water policies. At present, pressure from everyday water management delays serious reforms in water sector. The national water management systems are mainly focused on solving urgent daily water needs. The absence of well thought out, systematic national water policies have resulted in conflict of interests at the regional (transboundary) level.

As the external aspects of the nation building are more politically sensitive, they have far reaching impact on transboundary water management. Having set up most of the attributes of the nationhood, the regional states feel more confident in defending their interests openly in connection with shared resources, including water resources.

Differing Water Systems (Governance)

Since the 1990s, the Central Asian states build different governance regimes; each country has its unique political and economic set up despite their common history - part of the same state until their independence and having similar socio-political and economic system during the Soviet regime.

Having set an introduction into the water management issues of Central Asia, it is essential to understand how the transformations in the water sector of Central Asia happened. Since the 1990s, the water sectors of the regions have been transformed from state-led and state-funded into different types of water management systems (see Table 7.3.1).

Table 7.3.1 Water Management systems in Central Asia (Abdullaev, 2013)

Water management systems (governance)	Water system elements
State led and state controlled (state centric):	✓ weak users organizations (Water Users Associations - WUAs) ✓ State funded and controlled Water Management Organizations (WMOs) ✓ Territorial water management with some basin management elements ✓ Water is a security issue
Decentralized water management:	✓ Emerging viable WUAs ✓ limited state support ✓ Basin management
De-regulated water management:	✓ local water management ✓ WMOs are incapable to implement water policies ✓ National policies are de-linked from local realities

The differences in the water systems were attributed to the differing national water policies of the Central Asian states. The water policies although following internationally sound principles (e.g., Integrated Water Resources Management-IWRM) are outcome of distinctive policy making in each country. Therefore, the Central Asian states have different water management systems at the national level.

State-led and state-controlled water management systems are common in the countries with strong state apparatus and a high share of water sector state funding of. In this system, the state is present in the water sector throughout the nation building and transition period. The state determines policies and practices of water management both at the national and local levels. Water is a national security issue and decisions are made at political level where the state water management organizations are only implementing bodies. The overwhelming state control on water management has resulted in weaker water user organizations and no space for private participation (Aminova and Abdullaev, 2009).

The decentralized water management systems emerged in countries with growing relatively plural economic system and privatized agriculture production. In this system the state has the role of policy making; implantation of the policies is distributed among a wide range of players: the state water management organizations, private operators and individual and groups of water users.

De-regulated water management is attributed to weak states. Limited financial and economical means led to the abandoning of the water management. The absence of viable users' organizations and strong private interest led to anarchy in water management. The water management became a playground for different fractions to control electorate in different elections. The role of the state water management organizations is often limited to collection of irrigation service fees.

Economic growth

In the mid-2000s, after decade of stagnation and economic decline, the Central Asian states started to grow steadily. The economic growth differs from 11% in Turkmenistan to 5-6% in Kyrgyzstan. This growth can be attributed to the high price for oil, gas and other natural resources and to the structural changes in the economy. Central Asian states have transformed their economies from one that is centralized and state-planned to one that is more market driven. Two of the Central Asian states are members of World Trade Organization- WTO and one is in the process of accession. In parallel to the public economy, vibrant and competitive private sector is present almost in all countries. The private interests are well secured in water provision as well.

The economic changes were shaping in some degree in water management policies. All the regional states have introduced water service fees for different sectors. The private interests are lobbying for changes in the water legislation and water management practices in order to secure access for the water. Private investments into the water infrastructure are an emerging trend. Private interests are well presented in water sharing disputes at the regional level. The energy companies, irrigation farming community, industrial groups, both national and transnational, are taking part indirectly in the discussions over water sharing among the riparian states. Moreover, further economic growth will fuel request for energy, food and therefore will increase the competition for the water resources.

Social Changes

Recent political and economical reforms abolished society of "equals" in the Central Asian states. More of private interests are prevailing in different aspects of life as power of money and resources are growing. Moreover, the social infrastructure of the Soviet era that provided some degree of social security for most of the population gave way to more pragmatic policies with economic drive. Groups of people, especially in the rural areas became socially unprotected and dependent on subsistence farming. This is further exacerbated by the recent agricultural reforms, as a result of which agricultural production now is individual responsibility of farmers (Figure 7.3.2).

The water management system that dealt with collective farming in everyday water management is not capable of coping with individual and plural production systems. Therefore, poor people have difficulties in accessing water resources. Without proper local water users' organizations, social stratification and power differences will be a major obstacle for sustainable water management in the region. Social protests over the access to water resources became regular events in rural areas of Central Asia in the last few years. The danger is that these water-related social protests are fraught with social unrest instigated by both internal and external forces alien to the current governments.

Current Trends

Water sector reforms, Integrated Water Resources Management

Recently, the regional countries started to make serious attempts to reform their water sectors. The driving factors of the water sector/IWRM reforms in Central Asia were: (i) overall reforms of the state apparatus, nation building process; (ii) reduction of for water sector budgeting; and (iii) water management problems: huge and inefficient water management system and of course, pressure on the part of international donors and lack of international funding opportunities.

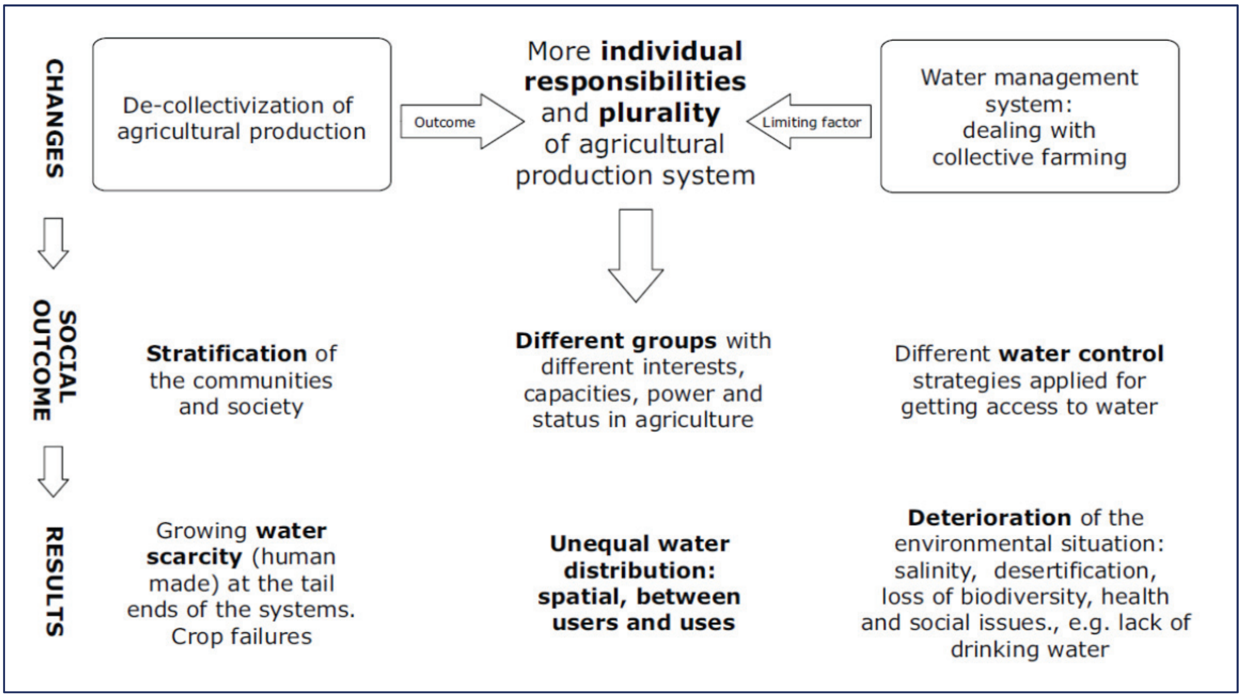

Figure 7.3.2 Impact of socio-economic changes on water management at local level (Abdullaev et al., 2009)

In terms of progress in the implementation of IWRM, Kazakhstan is most advanced, where both legal and institutional environment for IWRM have been set up. Quite a lot of progress has also been made in Uzbekistan, where basin organizations are set up for irrigation water management of. With the implementation of recent water sector reforms Tajikistan is also heading towards IWRM. Kyrgyzstan, having set right both legal and institutional conditions, is still lacking a systematic political support for the process. In Turkmenistan, recent steps have been taken towards setting up a platform for discussions on water sector reforms (Abdullaev, 2013).

Data and Information Sharing

Data collection and reporting requirements in the water sector of the Central Asian countries has not changed much from the Soviet era. A huge effort has been made in the last decade or so by the regional organizations (such as the Scientific Information Centre of the Interstate Coordination Water Commission (SIC ICWC), the Executive Council of the International Fund for the Aral Sea (EC IFAS), etc.) to systematize data on water resources. The databases developed during this period cover different levels, aspects and regions of Central Asian water management. Raw data are collected and kept at the lowest water management levels with limited or no access for either by the higher water management hierarchies or the public (Abdullaev et al., 2012). However, efforts have been made to build up regional and national water information systems; this resulted in the acceptance of the role of such systems in improving water resources management.

Regional Institutions and Platforms

Central Asian states have set up regional cooperation organizations on water management immediately after the collapse of the Soviet Union. The regional states set up institutions to effectively deal with the disintegration of the joint water management institutions of the Soviet era.

There are two Basin organizations for Syr Darya and Amu Darya organized since in 1980s. Then, in 1992, after the collapse of Soviet Union, 5 Central Asian states set up Interstate Coordination Water Commission (Inter-state Commission for Water Management) (SIC ICWC) responsible for water issues. Currently, the regional institutions are organized under the umbrella of International Fund for the Aral Sea (IFAS), which was set up in 1994. In 1997, the Interstate Commission on Sustainable Development (ICSD) has been organized for cooperation on issues of sustainable development. The Regional Environmental Center for Central Asia (CAREC) was organized in 2001 to serve as a platform for cooperation between the state, civil society and business sectors on environmental problems.

Water agreements set up during the Soviet era and were used as a basis for further water sharing between Central Asian states. Participation of the presidents of all the states in the most important events of the regional organizations ensured strong political support to these regional institutions. The regional institutions are indigenous initiatives with limited support on the part of the international donor organizations .All the countries are presented in regional institutions by equal number of representatives and the decisions are made on a consensus basis.

At present, regional institutions are facing a number of challenges related to the new political, economical and social settings in the partner countries. First and foremost, national interests of the regional countries have been clearly set up, which is in contradiction with water arrangements set up in the Soviet era. Secondly, these regional institutions have to receive considerable support from the founding members for the organization of their work. This will create ownership by Central Asian countries for both regional processes and institutes. Thirdly, the role of the regional organizations in development of the water policies is rather decorative and limited. Moreover, trust and mandate for the regional organizations have been drastically reduced in the last few years. Therefore, a fresh start could be good in order to assure both the national and international players as to the role of the regional institutions in improvement of water management.

Conclusion

The national water management systems have been focused on solving urgent daily water needs. The absence of well thought out and systematic national water policies have caused conflict of interests at the regional (transboundary) level. Moreover, the overwhelming state control on water management has resulted in weak water users organizations and left little space for private participation. In contrast, in countries where the state does not play significant role in water management, the water management was used as a tool for different fractions to gain control of the electorate. Further economic growth will fuel request for more energy, food and therefore increase competition for water resources. It is

important to note that the social protests over the access to the water resources have become regular in the rural Central Asia in the last few years.
The external aspects of nation building are more politically sensitive and will have far-reaching consequences on transboundary water management. Newly formed states are now more confident in defending their own interests in the field of resources, including water resources.

The main obstacles to a successful water sector reform are the overall political systems in Central Asian states where they are still state-centric and authoritarian. The water sector is facing capacity problems and the lack of committed and experienced experts. Reform initiatives are led by international donors where local knowledge and political agendas are overlooked or ignored. Partners from the national water agencies are trying to channel funding towards hardware improvements. That although crucial, is not the single most important component of the water resources management.

Informed decision-making on issues of water management depends on the availability of the data at the operational levels. Improvement of data management is a part of overall solutions to water problems. Therefore, improving the management system transparency of through data tools could lead to more sustainable water resources.

7.4 Application of a Water Framework Directive approach in Kazakhstan

Lian Lundy, Burghard Mayer

E-mail address: L.Lundy@mdx.ac.uk

Introduction

The Water Framework Directive (WFD) (EU WFD, 2000) is a legislative framework with an overall objective of ensuring that all surface, ground and coastal waters throughout the European Union achieve good ecological status by 2027 (see chapter 6.1). Two of the key requirements of this single legislative framework are that:

- water resources are to be managed at a river basin level as opposed to a national or administrative unit level
- river basin management plans must be developed collaboratively with all water users and those who are impacted by water management decisions (i.e. stakeholders)

In other words, the WFD requires all members of the EU to implement an integrated water cycle management (IWCM) approach, and sets out a set-by-step programme by which this can be achieved (EU WFD, 2000). The WFD is being implemented over 3 management cycles, the first of which ends in 2015. By this date, EU Member States (MS) are required to have:

- classified the ecological, chemical and hydrogeomorpological status of all its water bodies, including the establishment of transboundary initiatives to facilitate the management of waters that cross national boundaries
- established reference conditions for 'natural' water body types as a benchmark for defining 'good ecological status'
- enabled and facilitated catchment stakeholders (e.g. water companies, industry, regulators, local government, agricultural sectors, public, NGOs etc) to work in partnership to develop and implement 'programmes of measures' i.e. a series of actions which will enable all water bodies to reach 'reference conditions'

Challenges in IWCM in Kazakhstan

In Kazakhstan, the Committee on Water Resources (CWR; a state authorised organisation) manages water use and its conservation at a national level and oversees the activities of regional and local water management bodies (see chapter 6.4). Following its establishment in the early 1990s, the CWR participates in a range of activities from the development and implementation of policies for the use and protection of water resources to adopting standards for water use and cooperating with neighbouring countries on water aspects (FAO, 2013). Within each of Kazakhstan's eight river basins, the CWR has established a basin water management unit. These sub-divisions of the CWR are responsible for the implementation of a range of integrated water management activities at a catchment scale, including co-ordination between a basin's water users, protection of water resources and compliance with water legislation. Hence the need for an IWCM approach involving strategic management at a regional level and consultation with a range of stakeholders is recognised in European, Kazakhstan and Central

Asian contexts, and legislative developments to support its achievement have been taken (see chapters 7.1 and 7.3).

The following sections consider the drivers for an IWCM approach in both Kazakhstan and the EU, including an overview of key commonalities and differences in the challenges facing water managers and their impacts under current conditions. Furthermore, as a contribution to supporting both regions as they progress towards their stated objectives of transitioning to an integrated approach to managing finite water resources, the need to develop IWCM strategies which can adapt to a changing climate are also highlighted (UN ECE 2009). Table 7.4.1 gives an overview of aspects to be considered within this dual IWCM-climate change agenda. Further information on each of the issues identified can be found within earlier chapters of this textbook.

Table 7.4.1 Key aspects through which IWCM strategies can address adaptation to climate change (UN ECE 2009)

Key aspects
Core principles and approaches
International commitments
Policy, legislation and institutional frameworks
Information and monitoring needs for adaptation strategies design and implementation.
Scenarios and models for impact assessment and water resources management
Vulnerability assessment for water management
Adaptation strategies and measures
Financial matters
Evaluation

Drivers for change

Water bodies – including rivers and lakes, groundwater and coastal waters - are vital resources on which all life depends (JNCC, 2010). The ecosystem services and goods they provide include water for drinking, washing, bathing, agriculture and industry. Water bodies provide valuable habitats for a host of terrestrial and aquatic species (including genetic resources) and opportunities for recreation, as well contributing to the delivery of a range of indirect benefits; from mitigation of the urban heat island effect and urban flooding to the provision of carbon sinks. However, throughout the world, including many areas in Central Asia and Europe, countless water bodies have been seriously impacted by a range of human activities (MEA, 2005). These include processes such as drainage and over abstraction to meet agricultural requirements reducing water volumes associated with many surface and groundwater bodies and pollution from domestic and industrial wastewaters negatively affecting their water quality and associated ecological status. Key examples of this trend include the loss of much of the Aral Sea after the 1960s (see Figure 7.4.1) and the declaration of the River Thames (London, UK) as biologically dead in the 1950s (see Figure 7.4.2).

Protecting and enhancing the status of aquatic resources is a central component in supporting our shift to a sustainable economy and IWCM is seen as a key mechanism to support its delivery. The Global Water Partnership (GWP, 2000) defines IWCM as a process which maximises "economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". As an approach, IWCM is not without its criticisms; for example, Molle (2008) describe it as a woolly and unwieldy concept that can be derailed by political agendas. However, others such as Butterworth et al., (2008), whilst remaining sympathetic to such criticisms, argue that as a philosophy (as opposed to a package of solutions) it has considerable value. In this paper Butterworth et al. (2008) suggest various possible ways forward in implementing this "multi-interpretable concept" which include building on and supporting the development of existing mechanisms for stakeholder participation and local arrangements for water management, in contrast to trying to implement wholesale change from ground level.

Figure 7.4.1 Aral Sea sea-ground: today a desert (Photograph B. Meyer, 2014)

Figure 7.4.2 River Thames water pollution in 1952 (Photograph: A Harrison, 1952)

Commonalities and differences between Kazakhstan and the EU

The quantity and quality of surface water and groundwater bodies in both Kazakhstan and the EU have been seriously degraded as a result of a range of human activities operating over a variety of physical and time scales. As in all regions of the world, the distribution and hydrology of water resources follow natural not political boundaries, and the policies and practices in one country can affect the supply and quality of water in another, especially for down-stream or 'tail-end' water users. Hence changes taken at a national level can have major implications on a regional basis.

Facilitating the management of water resources on a transboundary basis is a major issue throughout Central Asia, but particularly in Kazakhstan as a downstream user in seven of its eight river basins. However the development of transboundary management practices is also a huge challenge in Europe where 75% of its river basins are transboundary (EC, 2012) offering ample opportunities for sharing and exchanging experiences between regions. For example, any increases in the abstraction of water from the Rivers Or and Black Irtysh would have huge implications for the continued viability of Kazakh fishery resources in terms of the generation of low flow zones, reduced connectivity between ponds and the loss of spawning grounds (see chapter 7.2). In the EU, following a series of major floods in 2002 and 2013, many of the current concerns related to the management of transboundary waters focus on the management of flood flows and how the types and locations of flood defenses in one area can impact on flood levels further downstream (De Roo et al., 2003). Whilst addressing contrasting aspects of water management, the need for transboundary dialogue and co-management of water resources across national boundaries with differing national priorities, concerns and institutional arrangements remains the same.

With global travel now an everyday activity, no country is immune from inadvertently generating or receiving non-native species. Many non-native species are not of key concern in that their presence does not have a serious negative impact on a country's native species, health or economy (NNSS, 2014). However, in both Kazakhstan and the EU, the presence of several non-native animals and plants have been recorded which do have the ability to spread and cause damage. Species falling into this latter category are referred to as invasive or alien species, and waterways and related water activities have been identified as a major route via which both invasive plant and animal species can spread. For example, a recent UK study estimated the annual cost of invasive plants and animals species to the UK economy was £1.8 billion, with the impact on waterways (including boating, angling and waterway management) estimated to be £57 million (Kelly et al., 2014). Despite their widely differing geographical and climatic conditions, the EU and Kazakhstan do have some invasive species in common including the American mink (*Mustela vison*) and the carp (*Cyprinus carpio)* (NNSS, 2014; GISD, undated).

In moving towards implementing an IWCM approach, there are also key differences facing the EU and Kazakhstan. Many countries within the EU have a long history of collaborating over the management of water resources (primarily for economic purposes), with bilateral agreements covering major rivers and lakes straddling national boundaries in place for decades (UN ECE, 2011). Such activities taking place over extended periods of time have engendered the development of trust between partners, leading to the expansion of areas covered by agreements and facilitating the implementation of an IWCM approach. In contrast, the state of Kazakhstan is a relatively new entity of just over 20 years old which, as it increases its stability and establishes its national identity, is beginning to have a greater focus on the development of transboundary relations. The impact of this differing timeframe over which European and Central Asian countries have had the opportunity to develop IWCM relationships can clearly be seen through a comparison of the numbers of transboundary agreements covering all shared waters in he EU with those agreed for the Central Asian countries (Figures 7.4.3 and 7.4.4). Whilst comparatively fewer bilateral agreements which cover all shared waters have been agreed within a Central Asian context to-date, progress has been made and it is anticipated that further agreements will be developed as transboundary relationships mature.

Benefits of implementing a WFD approach in Kazakhstan and Central Asia

Whilst both the EU and Kazakhstan are moving towards implementing an IWCM approach, the launch and phased implementation of the WFD has greatly accelerated progress towards its full implementation throughout Europe. As a single piece of legislation that all MS must implement, it requires the collection of data, involvement of all stakeholders and the development and implementation of science-based programmes of measures via the use of common methodologies and processes. All data collected is freely available with the use of common methodologies promoting the harmonization of management approaches both within and, crucially, between Member States. As such, this transparent approach facilitates transboundary dialogue with the development of common goals, languages and tools identified here as a strong mechanism for intra regional co-operation.

Whilst the adoption of legislation such as the Kazakh Water Code indicate the recognition of, and priority placed on IWCM within Kazakhstan, no single country which shares transboundary waters can fully implement an IWCM approach in isolation. Whilst arguably not a short-term objective, the need for a Central Asian Water Framework Directive approach which would co-ordinate and harmonize the emerging activities taking place across the region is ambitiously identified as a priority requirement. In developing such an over-arching framework, the aspects identified in Table 7.4.1 can be considered as an initial agenda for discussions to strengthen partnerships between business, regulatory and academic sectors at a national and international level to face the common need to implement robust approaches to water resource management in the face of a changing climate.

Conclusion

In developing and implementing approaches to ensuring water resources are available to meet the needs of current and future generations, Europe and Central Asian are facing many common challenges. The opportunity for closer collaboration between regions is highlighted here, with regard to both the need to develop a regional approach to IWCM and the role that individual countries can play in contributing to its delivery. With a specific focus on supporting the development of IWCM within Central Asia, the following key challenges are identified:

- Persuading neighboring upstream countries that it is in their interest to work on a catchment basis
- Developing increased collaboration as opposed to competition over use of water resources within catchments e.g. tensions between agriculture and energy production
- Compliance with state legislative controls and facilitating stakeholder participation
- Scoping and developing a Central Asian Water Framework Directive; what can be learned from international best practice and mistakes?
- Developing the institutions and their capacities to successfully develop and deliver an IWCM approach which can respond to the challenges of a changing climate

In prioritising IWCM and investing strongly in their education system, Kazakhstan is well positioned to take a leading role in supporting Central Asia's transition to a region with a strong economy based on the sustainable management of its resources. To progress this ambition requires the focused efforts of substantial numbers of individuals who have been exposed to the multiple disciplines, concepts and tools required to deliver IWCM within policy development, practice and environmental regulation. As a contribution to meeting this need, this textbook provides a concise insight into key knowledge areas required including key concepts in IWCM and their best practice (Chapter 1); methodologies and supporting tools for IWCM (Chapter 2); management skills for building capability, capacity and impact (Chapter 3); best practice examples for water treatment management (Chapter 4); the management and sustainable use of water resources based on its geographical characteristics and features (Chapter 5); IWCM in Kazakhstan (Chapter 6) and practice on transboundary catchment issues and future integrated management (Chapter 7).

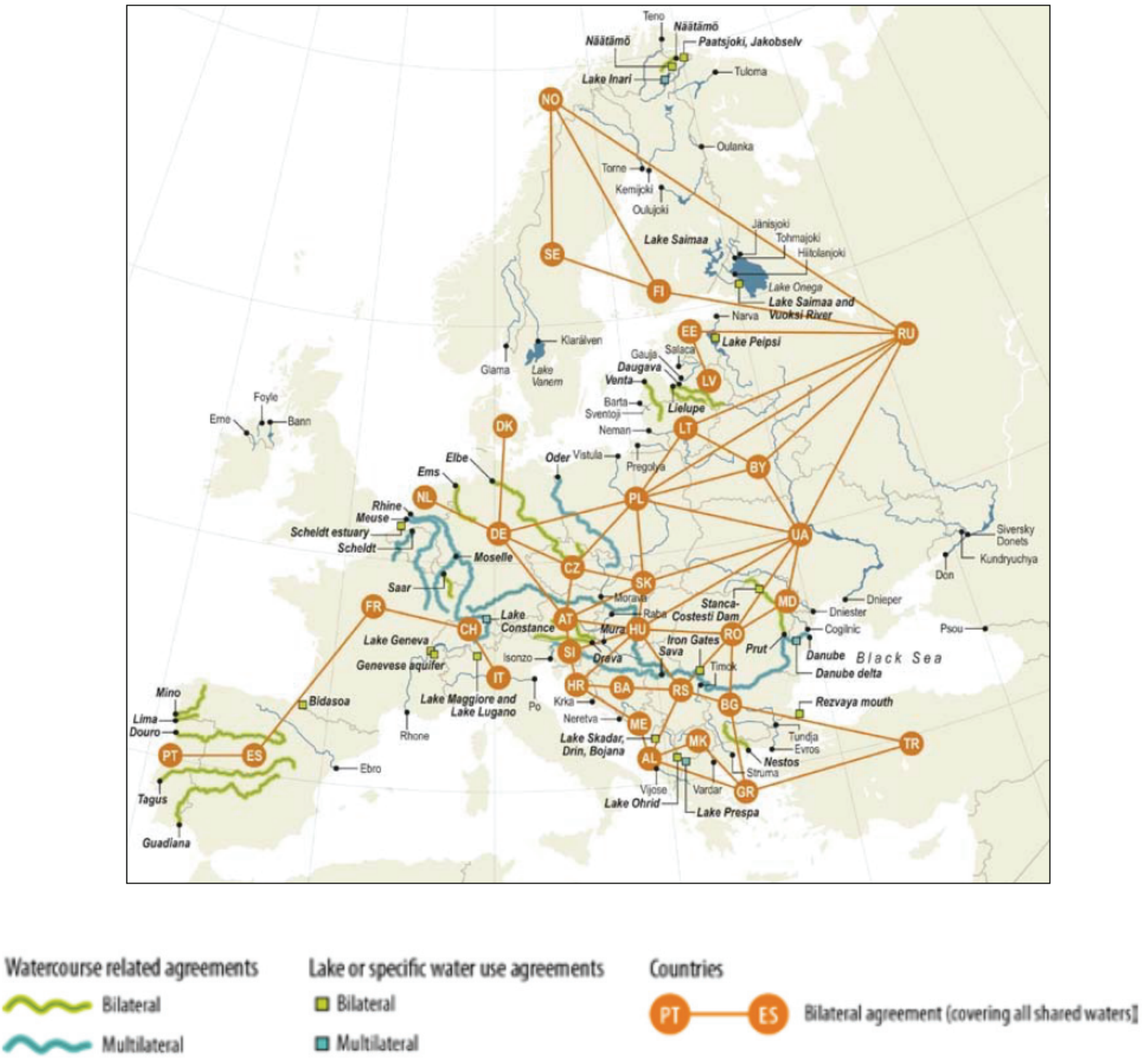

Figure 7.4.3 An overview of co-operations on transboundary waters in the EU (taken from UN ECE, 2011)

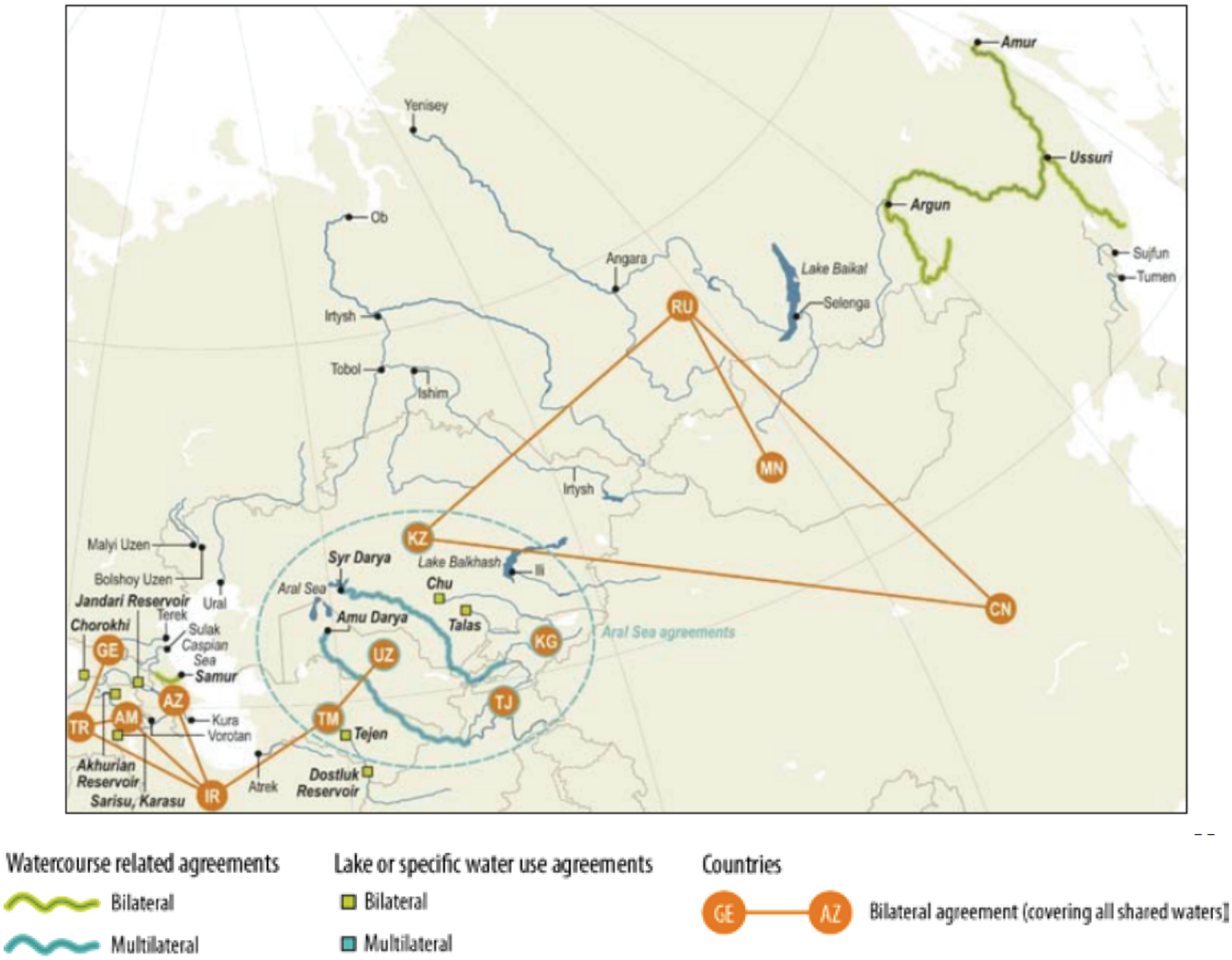

Figure 7.4.4 An overview of co-operations on transboundary waters in Asia (taken from UN ECE, 2011)

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Chapter 1 – Selected concepts in IWCM

1.1 Water bodies as providers of multiple ecosystem services, goods and benefits

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Chapter 5 – Sustainable use of water resources in Kazakhstan

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Chapter 6 – Integrated water cycle management for Kazakhstan

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Glossary

A glossary of key terms has been developed to help provide a common language for students and practitioners in the field of integrated water cycle management.

With kind permission of John Bryan Ellis, this glossary is developed by Burghard Meyer and Lian Lundy using many of the descriptions of water management terms as definitively defined in the "Urban Drainage: A Multilingual Glossary" (JB Ellis et al., 2006).

Acute (short term) pollution: an acute pollution event is one which causes an effect (usually death or a very serious physiological disorder in the organism) within a short period of time, normally up to 96 hours following an exposure event.
Ammonia Nitrogen: molecular (un-ionised) ammonia, NH3.
Application: an action of putting something to use (applications of models, theories etc.).
Aquifer: a geological formation or structure that can store and transmit water in sufficient quantity to make it economically feasible as a basis for water supply.
Baseflow: (a) the permanent component of flow in a sanitary or combined sewer; (b) the portion of streamflow which is supplied from groundwater and perhaps, interflow.
Basin: an entire tract of large territory drained by a single river, or contributing water flow to a single lake; in this sense the definition is identical to that given for a catchment or watershed. (**sub:** a subdivision of the whole entity, which is drained by one tributary).
Bioaccumulation: the process by which a pollutant builds up in the biological tissue of an organism due to its rate of excretion being less than the uptake rate.
Biochemical Oxygen Demand (BOD) : Particulate and dissolved organic matter (OM) as well as inorganic reducing species play an important role in domestic and industrial water treatment procedures and processes.
Biomass: the total quantity of organic material contained in or produced by an ecosystem. The term is commonly used in reference to the design of secondary biological treatment plants.
Biomonitoring: biomonitoring involves the systematic use of biological responses to evaluate temporal and spatial changes in the aquatic environment in order to provide information as a management tool for water quality control.
Canal: an artificial open channel.
Catchment/Catchment area: the surface area determined by topographical features that will drain runoff or a channel/sewer network to a single point (synonym for watershed or basin; more common in British English).
Chemical Oxygen Demand (COD): Chemical Oxygen Demand and the complementary BOD (See Biological Oxygen Demand) are water quality parameters designed to assess the dissolved oxygen which is available for the oxidative breakdown of organic substances within a polluted water sample.
Coliform bacteria: comprise all of the aerobic and facultative anaerobic, gram-negative bacteria that ferment lactose with gas formation within 48 hours at 35 degrees C. These bacteria are found in the guts and faeces of warm-blooded animals (including humans), cold-blooded animals and in soils.
Combined sewer: a combined sewer is designed to accommodate both foul wastewater flows and storm water runoff.
Combined Sewer Overflow (CSO): is flow from a Combined Sewer System in excess of wastewater treatment plant or interceptor carrying capacities released via a sewer regulator (or CSO control structure) to a receiving water body and/or to CSO storage/treatment facilities.
Conceptual model: in one sense, all models are conceptual since they consist of a concept or idea mentally constructed and then transcribed into mathematical terms.
Conductivity: a non-specific water quality parameter which measures the concentration of ions in solution due to their capacity to carry an electric current. The units of measurement for conductivity are µS/cm or mS/m (where S = Siemens).
Contamination: a process of making impure or unclean, or unfit for certain use, as in bacterial contamination.
Criteria: established factor or factors (standard) on which a judgement, evaluation or decision is based.
Debris/Detritus: sediments, plant matter and rubbish which may be carried along with stormwater flow.
Dendritic: applied to a stream or pipe network, this describes a tree-like or branched network, with flows occurring in only one direction.
Denitrification: is the process whereby nitrate is reduced to nitrite and then to nitrogen gas and ammonia; the process occurs in any nitrified effluent when deprived of oxygen i.e. under anoxic conditions.
Desorption: the desorption process represents the release of chemical species which have previously been adsorbed on to an active surface.
Deterministic model: a mathematical model in which all inputs are fixed or determined, and there are no probabilistic or random components, so that outputs will also be determined and unique.
Diffuse (Non-Point) pollution: pollution that arises from various land use activities such as urbanisation and agriculture and which has no obvious discrete source.
Directive(s): an official instruction given by a recognised authority. Usually contains certain standards to be implemented eg EU Water Framework Directive.
Discharge: the volume rate of flow passing through a predetermined section in a unit time.
Dissolved fraction: that part of a water sample which passes through a 0.45 µm filter.
Dissolved oxygen: although weakly soluble in water (about 10 mg/l or 0.3 mM at 10°C), oxygen is one of

the most important parameters for assessing water quality.

Drainage Area/Basin: the area of land drained by a stream or pipe network.

Dry solids: the dry solids content of a sediment or sewage sludge is the unit weight expressed as a percentage.

Dry weather flow (DWF): as it pertains to combined and sanitary sewerage or stormwater drainage systems, is the flow in a system that occurs during dry weather without a stormwater component.

Ecology: the biological science dealing with the relationships of organisms with each other and with their surrounding environment.

Ecosystem: a local biological community and its pattern of interaction with its environment. Ecosystems have both structural and functional characteristics that can be used as a basis to determine the relative health of the system.

Effluent: is the sanitary, industrial, or combined wastewater or stormwater discharged.

Empirical model: is a model founded on experience or experimental data only, not deduced from purely theoretical considerations.

Environmental flow: the flow regime required in a river to achieve specified ecological objectives.

Environmental (Water) quality objective (EQO/WQO): a target or statement of the quality to be aimed for in the receiving water body and which can then be used as a basis for programmes to secure the necessary improvements to achieve it and for deriving appropriate consent (or permit) limits to be imposed upon discharge authorisations.

Environmental (Water) quality standard (EQS/WQS): a standard normally expressed in quantitative terms specifying the maximum and/or minimum permissible levels for particular water quality parameters and at a particular location.

Erosion (raindrop, sheet, rill, gully, river bank): the loosening and wearing away of soils by different mechanisms such as raindrop splash where soil particles are dislodged and moved down slopes, sheet and rill erosion where running water moves soil particles, gully erosion where large channels or gullies tunnel into hill slopes, and river bank erosion caused by stream flows.

Eutrophic/Eutrophication: the trophic classification of lakes or ponds refers to the level of plant (primary) production sustained by a water body.

Evaporation: is the conversion of water held in or on soil, vegetation and bodies of water into water vapour through the input of energy.

Evapotranspiratation: is the process by which vegetation processes water taken in by the roots and transpires water vapour from its pores.

Field capacity: after infiltrating water has drained under gravity through the soil, that soil moisture remaining is defined as the field capacity and is essentially the water retained in the soil at a tension pressure of about 0.33 atmosphere.

Flash flood: a hydrological event of limited duration (measured in hours), which is characterised by a rapid rise in discharge and stage of streams or small rivers often occurring within a matter of minutes.

Flocculate/Flocculation: is the coagulation and agglomeration of colloidal and finely divided suspended matter to form gelatinous masses, known as flocs.

Flood: a hydrological event characterised by increased discharge, stage or water level in water bodies.

Flood plain: land adjoining stream channels which is subject to inundation by overflow (or overbank) flooding of certain frequency of occurrence.

Flow regime: flow regime refers to the hydraulic conditions in a system (eg piped drainage system, river).

Forecast: is a definite statement or statistical estimate of the occurrence of a future event and its specific attributes.

GIS(Geographic Information Systems): a procedure for developing a set of tools for collecting, storing, retrieving, transforming and displaying spatial data from the real world for the analysis of particular scientific and engineering problems.

Greywater: is non-drinking quality water, although originally of that quality, which has been previously used for one of various purposes, such as personal washing, clothes washing, etc. so as to affect its cleanliness.

Groundwater: is water resident beneath the ground surface which has its source in residual precipitation at the catchment surface infiltrating into the top soil and percolating downwards under gravity through the porous layers.

Groundwater recharge: is the result of deep penetration of waters through the overlying soil or rock down to the groundwater table either under natural gravitational percolation or by forced injection.

Groundwater table: the surface separating the unsaturated and saturated zones.

Heavy metals: The adjective `heavy' is used loosely to include not only metals of high relative atomic mass, such as lead, but a whole range of elements which can contaminate aquatic environments as a result of their presence in the dissolved phase or in association with suspended or settled particulates.

Implementation: a process of ensuring actual fulfillment by specific concrete measures.

Industrial water/wastewater (trade effluent): is primarily the specific liquid waste collected from industrial processing that has no further product recovery use. It contains various pollutants and toxic substances depending on the industry.

Infiltration (to a sewer): is the inflow of groundwater into a sewer or drain as a result of faults in the pipe jointing or of damage to the pipe.

Infiltration rate: the volume of water which may pass through the surface of a known area in a measured time. The units are often given as mm/h or mm/s.

Integrated water cycle management (IWCM): a strategic approach involving the coordinated management of water, land and associated resources to deliver economic and social welfare in an equitable manner without resulting in the degradation of ecosystems.

Integrated water resource management (IWRM): synonym for IWCM

Interflow: lateral movement of water within the unsaturated zone.

Landfill: an area of land or an excavation in which waste materials are placed for permanent disposal.

Land use: descriptor of land use which determines the amount and character of surface runoff and associated pollutant concentrations and loads e.g. agricultural, residential, commercial, industrial, highway etc.

Leaching: the removal of soluble constituents from soils or other material by percolating water.

Life cycle analysis/assessment (LCA): a process to evaluate the total environmental burdens to soil, water and air associated with the life cycle of a product, process or activity.

Load/Loading (pollutant): domestic and industrial effluents in urban areas contain large pollutant loadings which are complemented during wet weather periods in combined sewer systems by loadings associated with urban runoff.

Low flow: a general term referring to low water levels in a stream or river. **Measurement:** the process of collecting (measuring) data on a particular phenomenon (e.g. flow measurement, temperature measurement).

Microfiltration: in membrane filtration technology, microfiltration would retain particle sizes in the range 10^{-3} to 10^{-6} such as fine silt and pollen, whilst ultrafiltration (10^{-6} - 10^{-8} m) retains bacteria and colloidal suspensions with nanofiltration retaining the lowest size ranges (10^{-7} - 10^{-9}m) including, for example, virus.

Mineralisation: mineralisation is the process by which the organic matter is converted into inorganic compounds e.g. CO_2, nutrients etc.

Mitigate: to make less serious or severe as for example through introduction of policy or procedures intended to reduce pollution from specific sources.

Model: (simulation) is a mathematical approximation of the characteristics, relationships and processes of an actual physical system, in the form of computational algorithms attempting to reflect real cause-effect relationships.

Model: (mathematical) is a system of computational procedures presented as mathematical description of an entity or the state of affairs.

Model: (physical) is a miniature representation of an actual structure or entity (e.g. hydraulic models).

Monitoring: to watch, observe, check, regulate or control for a specific purpose (e.g. water quality monitoring, compliance monitoring).

Nitrites (NO_2): are very stable in water and are often present in treated effluents but as the oxidation of ammonia to nitrite by the Nitrosomonas bacteria is the rate limiting of the two distinct steps in the bacteriological oxidation of NH_3, it is unusual to find NO_2 in any appreciable concentrations in receiving water.

Nitrates (NO_3-N): constitute a very common form of nitrogen and comprise a highly stable, bioavailable species in well oxygenated environments.

Nitrogen: molecular di-nitrogen ($\underline{N_2}$) is one of the most common atmospheric constituents and is indispensible for vegetative growth.

Objectives: the purpose of a plan. Targets those are set when defining an activity or task e.g. desired/designated quality of receiving waters.

Observation: to note and record facts for scientific research.

Oligotrophic: the condition where the aquatic environment is poor in nutrient elements and where primary production is weak supporting only small numbers of organisms of many different species.

Open channel: a channel where the water surface is open to the atmosphere, so the water has a variable free surface. Closed conduits such as pipes can operate as open channels if they run part-full.

Organic Matter (OM): is a primary pollutant form used for the assessment of the quality of urban drainage waters, suspended solids (SS) and sewer deposits.

Oxidation pond: a shallow lagoon or basin within which wastewaters are purified through sedimentation and both aerobic and anaerobic biochemical activity over a period of time.

Pathogen: a microorganism or virus that causes disease.

Peak flow or Peak discharge: is the maximum rate of discharge occurring in a natural stream, artificial channel or pipe during a runoff event.

Permanent flow: a flow which is maintained at all times, by baseflow from groundwater and/or by human sources such as discharges from industry.

Pesticides: a group of mainly organic chemicals which include fungicides, herbicides, rodenticides and insecticides.

pH: a number denoting the common logarithm of the reciprocal of the hydrogen ion concentration.

Phosphate/Ortho-Phosphate/Phosphorus: Phosphorus is a key element required to sustain growth of plants including algae.

Pipe: a closed conduit manufactured in various materials, capable of conveying a fluid from one point to another.

Plan: a detailed formulation of program of action.

Point source (pollution): Point source is any discernible confined and discrete object from which pollutants are or may be discharged e.g. effluent discharge point of an industrial or municipal wastewater treatment plant.

Polluter-pays-principle: an effluent charging system intended to achieve environmental quality objectives at least-cost to the community, by reinforcing the philosophy that the polluter should be responsible for all aspects of pollution control in relation to their own effluent.

Pollution, pollution load, pollution flux, and pollutograph: each describe the condition of the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects or impacts.

Policy: a definite course or method of action selected from various alternatives, in view of specific conditions, to guide and determine present and future decisions.

Precipitation: water of atmospheric origin which falls to the earth in the form of rain, snow, hail or sleet.

Public involvement: procedures for informing and/or involving the public in the development and delivery of activities such as the development of catchment management plans..

Qualitative: pertaining to the non-numerical assessment of a parameter.

Quantitative: pertaining to the numerical assessment of a parameter.

Rainfall-runoff model: a model, usually in mathematical form, which converts rainfall inputs (e.g. in mm) to runoff volumes (e.g. in m^3).

Rain Gage/Gauge/Recorder: the rain gage (US) or gauge (UK) is a device for measuring the depth of rainfall at a specific point.

Real time: dynamic processes such as runoff, flow, pollutant transport etc., can be described by using a range of variables that change over time. If this process time is equal to the current (clock) time the process is said to occur in real time or on-line.

Regulation: is a specific law that applies in all relevant situations.

Regulating reservoir: a reservoir with dynamic control of releases of stored water designed to meet various water management objectives.

Release rate: the rate of discharge in volume per unit time from a detention storage facility or reservoir

Relief sewer: a secondary drainage system designed to operate via connections or overflow(s) from an overloaded main system during times of high flow rate or blockage.

Residence/Retention time: the average time that water passing through a tank or waterbody spends within a specific storage facility.

Restoration: the act of returning something such as a channel, habitat or water quality to its original condition prior to anthropogenic disturbance.

Reuse: the practice of recovering, treating and using water which has already been used for a purpose such as water supply.

Risk: the chance or probability of loss or damage on exposure to a define hazard.

River: a large, natural stream.

Runoff : the portion of precipitation on a specified drainage area, or other flow contributions, that are discharged from that area into receiving waters.

Salinisation: an increase in the salt content of soils, which can be caused by alterations to natural drainage regimes.

Sealed area: is a relatively impervious land-surface area that is covered, paved, or lined with impervious materials so that surface runoff cannot readily infiltrate through the layer into subsurface zones.

Sediment: any particulate material (mineral or organic) which is able to settle in a fluid.

Sediment transport: a term commonly used to cover all aspects of the movement of sediment particles throughout a catchment system.

Seepage: the outward escape or exfiltration and movement through the ground of effluents from all components of a drainage system.

Self-purification: although most micro-pollutants are transferred from water to solid adsorption sites and disposed of rather than really eliminated, organic matter (OM) may, in aerobic conditions, evolve into carbon dioxide and return to the atmosphere.

Settlement: a small community (village).

Sewershed or Catchment: is an urban drainage area (catchment) in which all subcatchment surface runoff and wastewater treated or untreated from the land areas are collected by the sewer systems, treated or untreated, and then discharged to the receiving water.

Simulation: the imitative representation of a real world process / system over time; examination of a problem by means of a simulating device.

Sludge: a semi-solid residue produced from various water treatment processes.

Solids: particulate material either in solution (suspended solids) or has settled out of solution to form a sludge or sediment.

Sorption: the generic term applied to the physical or chemical binding of one substance to another.

Standard: an authoritative or recognised exemplar of correctness or some definite degree of quality. Standards are usually formalised to represent best current practice and may be legally binding.

Stochastic model: describes the characteristics, relationships and processes of an actual physical system involving the use of probability levels for each of the variables identified as a way to tackle uncertainty related to available data sets.

Storage capacity: the space (volume) available for storage of water in natural or artificial water bodies.

Storm: a period of precipitation within a catchment.

Stormwater (runoff): the water flowing over ground surfaces and in natural streams, artificial channels and pipes as an immediate effect of precipitation over a catchment.

Stormwater Best Management Practice (BMP): structural measures used to store or treat urban stormwater runoff to reduce flooding, remove pollution, and provide other amenities. Typical examples of BMPs include detention or retention facilities, infiltration facilities, wetlands, vegetative strips, filters, water quality inlets and others.

Stormwater retention basin/pond: basins which are intended to hold stormwater runoff and subsequently discharge it when the level of runoff subsides in the receiving water body.

Strategy: the art of devising plans to achieve a goal.

Stream: a small natural waterway flowing in a defined channel.

Subsurface flow: flow that occurs above the zone of saturation but beneath the land surface.

Surface water/flow: all runoff water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, wetlands, estuaries, seas etc.).

Suspended solids: the solids present in a water sample which are retained by a glass fibre filter paper followed by washing and drying or are deposited by centrifugation followed by washing and removal of the supernatant liquid.

Test: a critical examination, observation or evaluation.

Time lag/Lag time/Time offset: the time differential between e.g. time characteristics of the rainfall and runoff series (in runoff calculation) or flow records at points along a conveyance path (in flow routing).

Topography: the physical features of a surface area including relative elevations and the position of natural features.

Total Maximum Daily Load (TMDL): a method establishing the allowable loadings from all pollutant sources (both point and non-point sources) to a receiving water so that water quality standards can be attained.

Total Nitrogen: sum of all the forms of nitrogen.

Total Organic Carbon (TOC): the total amount of carbon in a sample determined by its total combustion.

Total solids: Total solids refers to the residue remaining following the evaporation of a water-sample and its subsequent drying in an oven.

Toxicity: The capacity of a substance or an effect to be poisonous or injurious to an organism.

Treatment: a term used for the removal of pollutants from wastewater, stormwater, or combined sewer overflow (CSO).

Trophic level: A successive stage of nourishment as represented by links in the food chain.

Uncertainty: is the quality or state of being indefinite or indeterminate (not known beyond doubt).

Unsaturated zone: the zone between the land surface and water table in which soil/rock pore spaces contains both water and air.

Uptake: the uptake of pollutants by aquatic species can occur either from water (membrane diffusion) or from ingested food.

Urbanisation: the conversion of rural areas into towns and cities, with alterations to catchment surfaces and drainage systems which alter natural water cycles.

Validation /ground-truthing (model): the process of proving the validity of a model on evidence or sound reasoning.

Verification (model): is the process of testing a model on an observed set of data using the model parameters derived during calibration.

Vulnerability: refers to the susceptibility to damage e.g. from inundation during flood events or receiving water impacts from industrial effluent discharges.

Wastewater treatment: wastewater treatment is the removal of pollutants from sewage or wastewater (including sanitary, industrial and stormwater flows) for the protection of public health and the environment.

Watercourse: any stream or channel which carries flowing water.

Water quality standards (WQS): officially recognised (and often legally binding) norms or examplars for the definition of water quality with approved methodologies and specified (consent) limits against which compliance can be judged.

Watershed: a topographically defined area drained by a stream or river such that all outflow is directed to a single point. (synonym for catchment).

Wetland: a generic term for an area that is regularly saturated by surface or groundwater and subsequently is characterised by a prevalence of vascular vegetative species that is adapted for life in saturated soil conditions.

Yield: the volume regularly available from a river or reservoir over a unit period of time.

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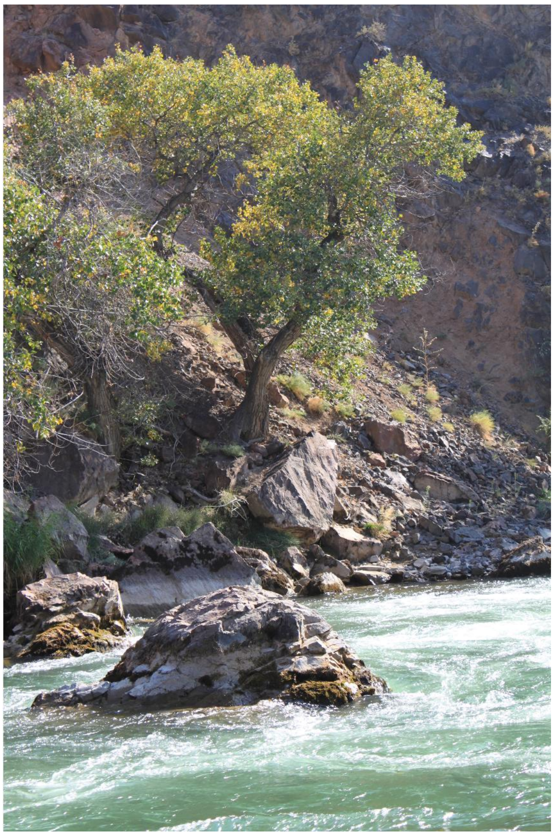

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